ELLIPTICAL ACCOMMODATIVE INTRAOCULAR LENS FOR SMALL INCISION SURGERY

FIELD OF THE INVENTION

This invention relates to intraocular lenses for implanting in the capsular bag of the posterior chamber of the eye after an anterior capsulorhexis. After implantation the lens makes use of the ciliary muscle to adjust the refractive power of the lens.

BACKGROUND OF THE INVENTION

Cataract extraction is the most common ophthalmic surgical procedure performed in the United States. Extracapsular cataract extraction involves cutting a portion of the anterior capsule (anterior capsulorhexis) followed by removal of the nucleus. Alternatively, a probe may be inserted through the anterior capsule and ultrasonically vibrated, transforming lens material into an emulsion is then irrigated and aspirated from the capsular bag (phacoemulsification). After removal of the natural lens, images no longer focus on the retina and a replacement lens must be provided for clear vision. Replacement lenses can be glasses, contact lenses or intraocular lenses. Of these, intraocular lenses give the greatest convenience and undistorted vision, however, for insertion of a lens, the size of the incision is dictated by the size of the implant rather than requirements of removing the natural lens. Replacement lenses, however, lack the ability of a natural lens to accommodatively focus on near and far objects.

When a person looks at an object, light is reflected from the object through the cornea, the aqueous humor, through the pupil and into the lens which converges the light through the vitreous body onto the retina. To clearly focus on near objects, light rays must be bent more. To accomplish this the lens becomes more curved and thicker. Most of this change comes from pulling and relaxing the capsular bag at its equator. The equator of the bag is attached to the ciliary muscle by filaments called the zonules of Zinn which are in turn attached to the ciliary muscle. When looking at an object in the distance, the ciliary muscle relaxes and expands, thereby pulling on the zonules, flattening the capsule and lens. When looking at a near object, the ciliary muscle tenses and contracts moving the muscle sightly inward and relaxing the pull on the zonules, allowing the capsular bag to become more curved and thickened from front to back. The lens itself is composed of interlocking fibers which affect the elastic movement of the lens so that as the lens changes shape the fibers alter their curvature. As a person ages, the accommodative ability of the lens decreases which changes in the eye. Age related eye changes include thickening of the lens, an increase in the amount of insoluble protein in the lens, a migration in the points of attachment of the zonules away from the equator of the capsule, and partial liquefaction of the vitreous body.

Lenses are made from transparent material having the shape of a body of rotational symmetry, such as a sphere. The degree of curvature of the surface is inversely proportional to the radius of curvature and the focal length. Parallel light rays converge after being refracted through a convex surface and diverge after being refracted through a concave surface. Refractive power of a lens is dependent upon the refractive index of the lens material and the lens curvature. A simple lens has two sides, each with a curvature. Two lenses separated by a given distance, can be considered as one thick lens having two foci and two principal planes. The focal length of the system is the product of their focal lengths (f_1, f_2) divided by the sum of their focal lengths minus the distance (d) between them i.e.

$$F=(f_1f_2)/(f_1=f_2-d)$$

When the space between the lenses is not a vacuum but contains a substance, the amount subtracted from the sum of the focal length is divided by the refractive index (n) of that substance.

$$F=(f_1f_2)/(f_1+f_2-d/n)$$

The refractive power of a lens system is given by the inverse of the focal length. By using two fixed lenses and varying the distance between them, a system of variable focal length can be constructed. If the curvature of one or both of the lens surfaces increases as the distance between lenses is increased, and decreases as the distance between the lenses is decreased, the change in focal length is enhanced.

Several attempts have been made to provide the eye with focal length accommodation. The most familiar of these is a bi or multi-focal lens. These are used in glasses, contacts, and intraocular lenses but have a disadvantage in that the focal accommodation is dependent upon direction of focus.

U.S. Pat. No. 4,254,509 discloses a lens which takes advantage of the ciliary muscle. However, this lens is placed in the anterior chamber of the eye. Such implants are at times accompanied by complications such as damage to the vascular iris.

U.S. Pat. No. 4,253,199 discloses a lens attached directly to the ciliary body. The lens is in a more natural position but requires suturing to the ciliary body risking massive rupture during surgery and bleeding from the sutures.

U.S. Pat. No. 4,685,922, incorporated herein by reference, discloses a chambered lens system for which the refractive power can be changed. Such alteration is permanent, accomplished by rupture of the chambers.

U.S. Pat. No. 4,790,847 provides a single lens for in capsular bag implantation using rearwardly biased haptics which engage the capsular bag at its equator and move the lens forward and backward upon contraction and relaxation of the ciliary muscles.

U.S. Pat. No. 4,842,601, incorporated herein by reference, discloses a two section deformable lens assembly for implanting in the capsular bag. The lens allows division of refractive power and takes advantage of the action of the ciliary body and zonules on the capsular bag. This lens system is assembled after insertion.

U.S. Pat. No. 4,892,543 discloses another two lens assembly for placement in the posterior chamber, possibly in the bag where the capsular bag is not removed. This lens allows dividing the refractive power between two lenses and introduces a variable focal length in one of the lenses by compressing a flexible wall of one lens against the convex surface of the second fixed lens. This requires that the first and second lens be in substantially adjacent positions.

U.S. Pat. No. 4,932,966, incorporated herein by reference, presents an accommodative lens in which two lenses joined at their periphery enclosed a fluid filled sack, accommodation being accomplished selectively changing the fluid pressure in the sac. One lens is a rigid